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(54) Apparatus and method for cementing a liner in a well bore

(57) An apparatus and method for cementing a liner in a well bore utilizes a setting tool 19 having an end 49 adapted to be connected in a pipe string for extension through the liner and having an opposite end. Seal means 59 are carried by a select one of the setting tool 19 and liner 21 for forming a seal between the liner 21 and the exterior of the setting tool 19 in the annular space which is created when the tool is extended within the liner. A wiper holder 99 is connected to the setting tool opposite end and has an interior bore 101 for receiving a wiper plug 103.

In the method, the setting tool 19 is lowered with the liner attached thereto into the well bore. Seals 59 on the exterior of the setting tool 19 engage the interior of the liner 21. The liner is then anchored in the well bore after which the setting tool 19 can be released from the liner. The setting tool is moved a selected distance to insure that the tool is disengaged from the liner with the wiper plug 103 being at least partly contained within the wiper holder 99 during such steps. Cement is then pumped into the liner through the operating string and setting tool mandrel. A pumpdown plug (not shown) sealingly engages the operating string and mandrel behind the cement and is pumped into engagement with the wiper plug 103. Cement is pumped out of the liner into the surrounding well bore by forcing the pump down plug and wiper plug through the liner. The setting tool is then removed from the well bore by withdrawing the operating string.

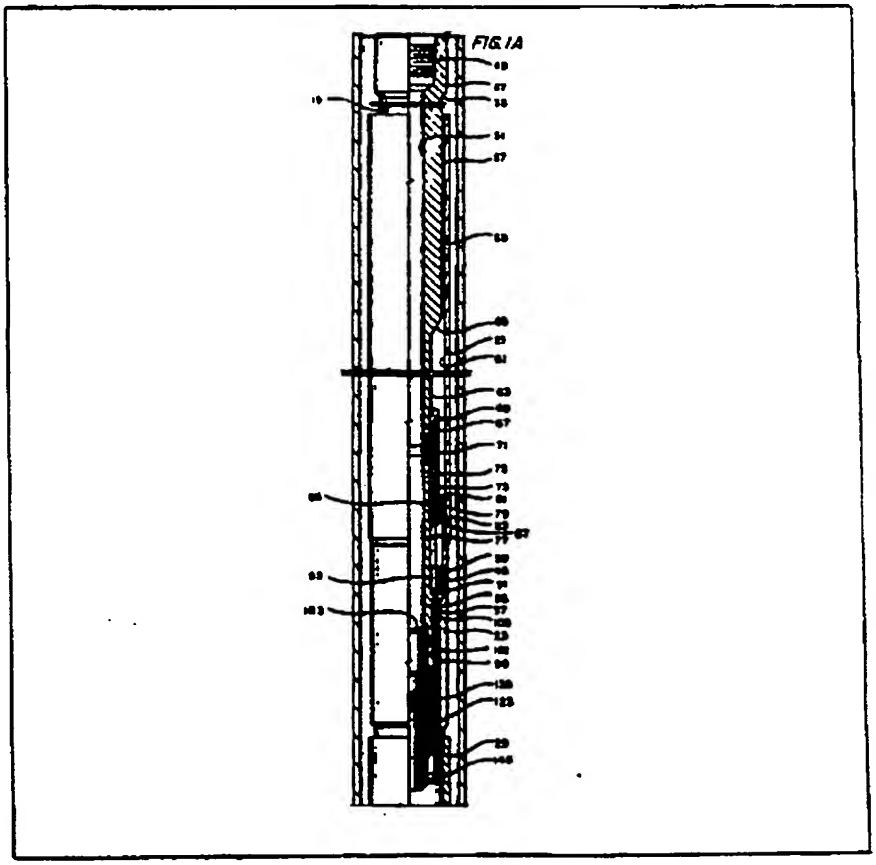

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FIG. 1A

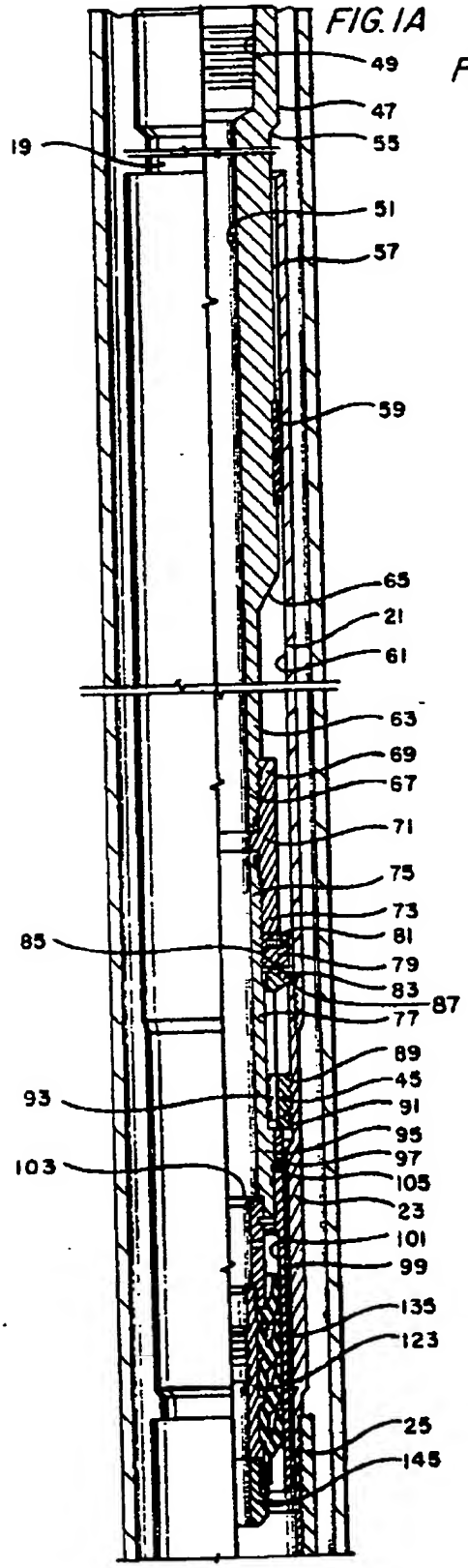
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FIG. 1B

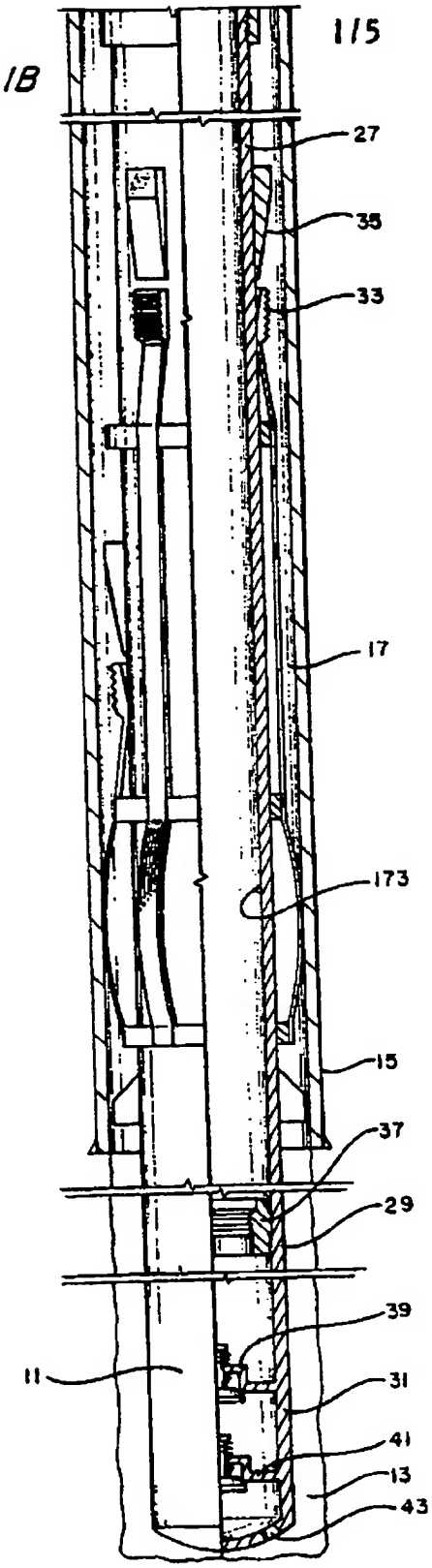
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FIG.2A

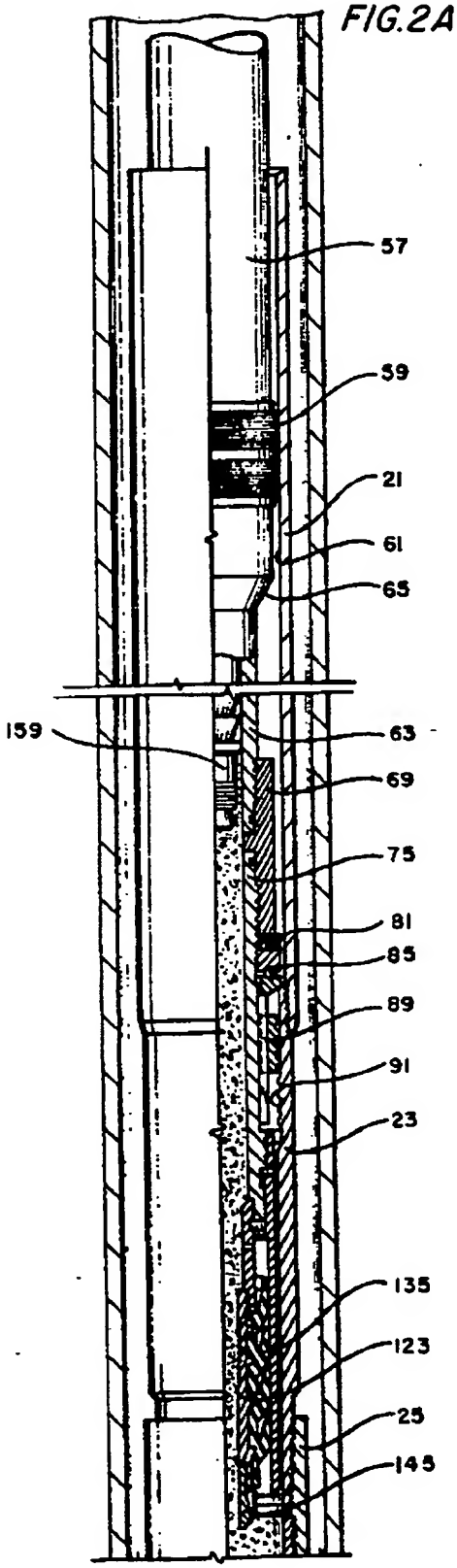
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FIG.2B

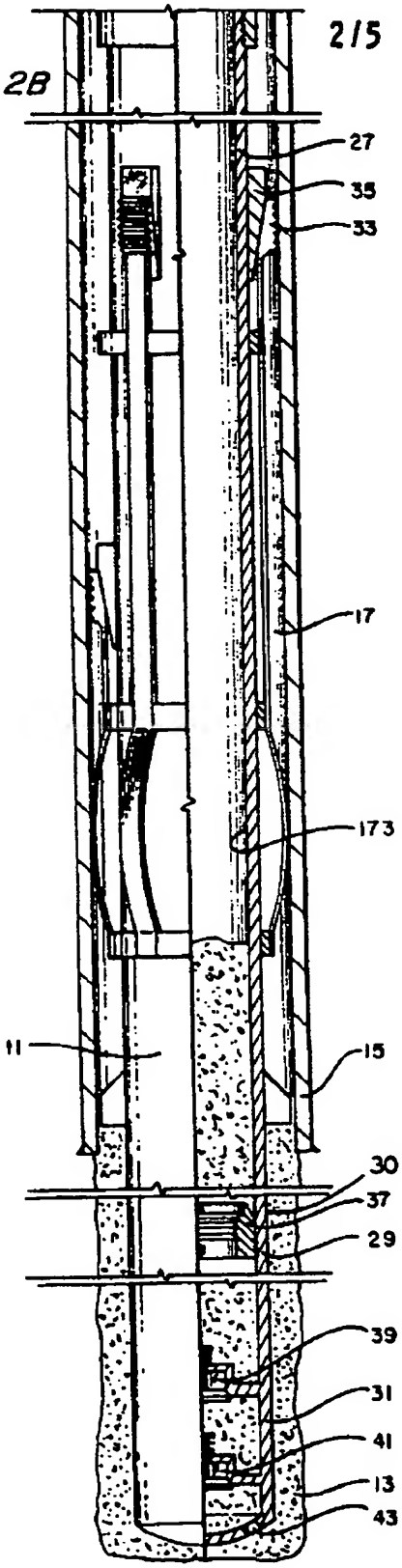
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FIG. 3

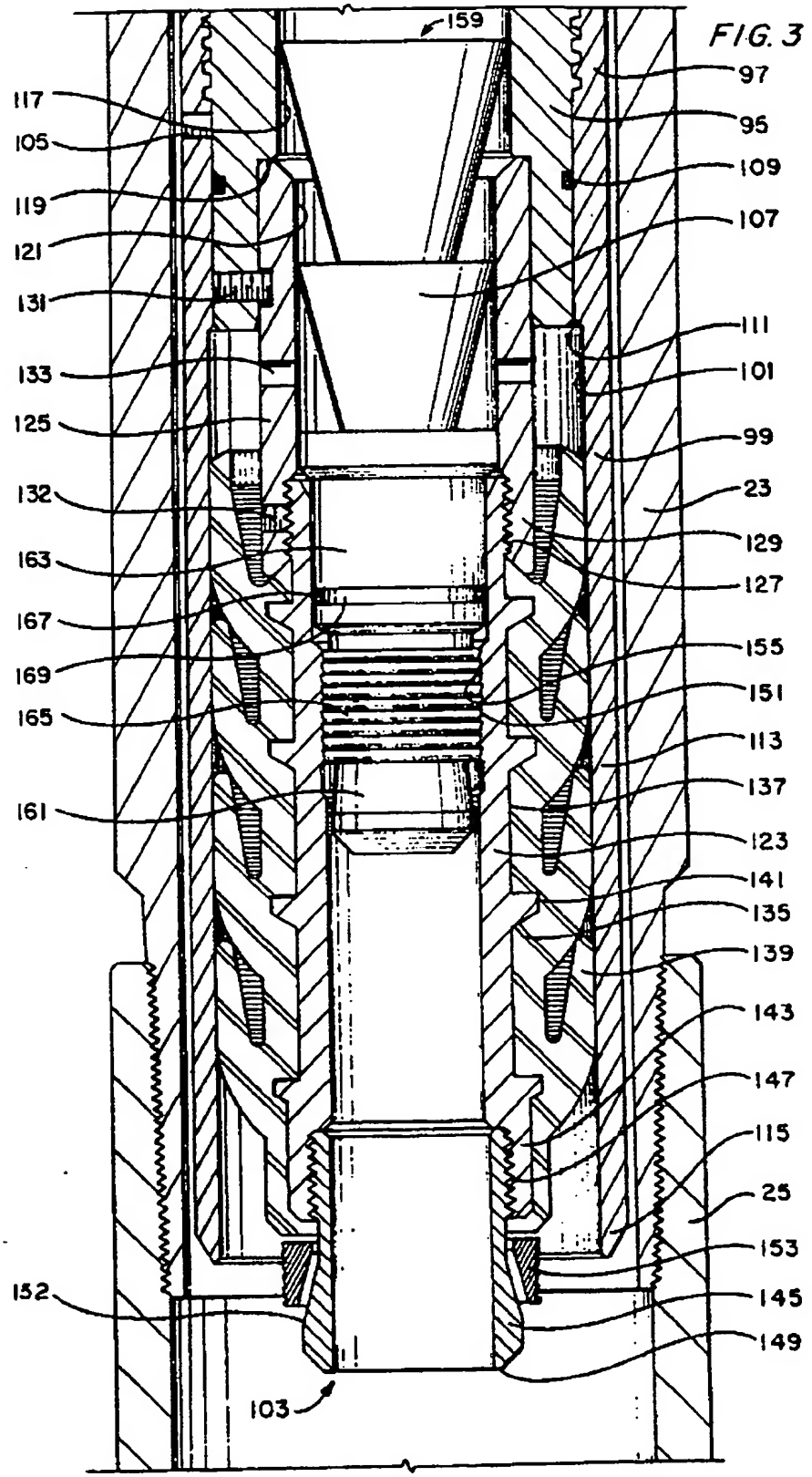
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FIG. 4

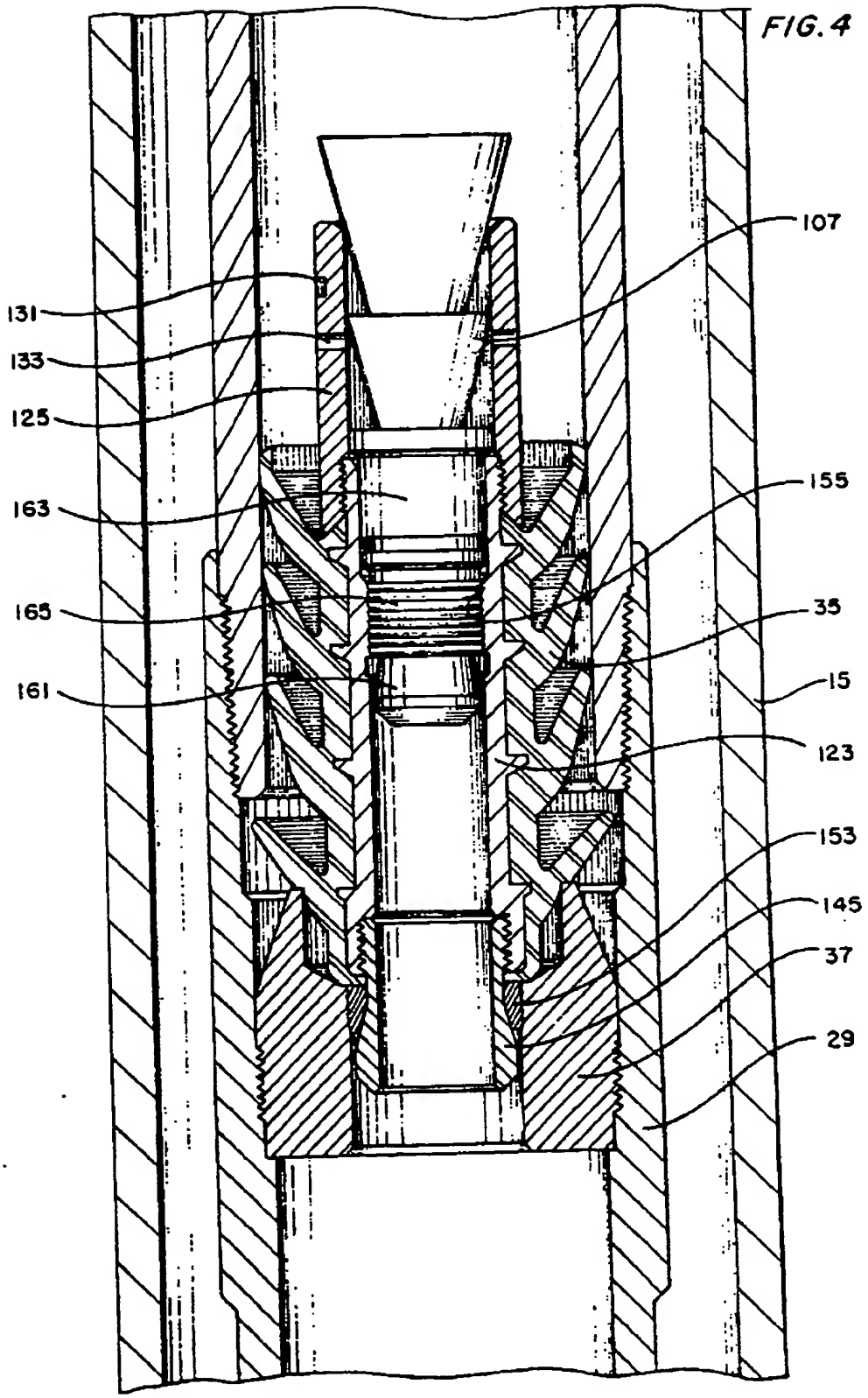

FIG.5A

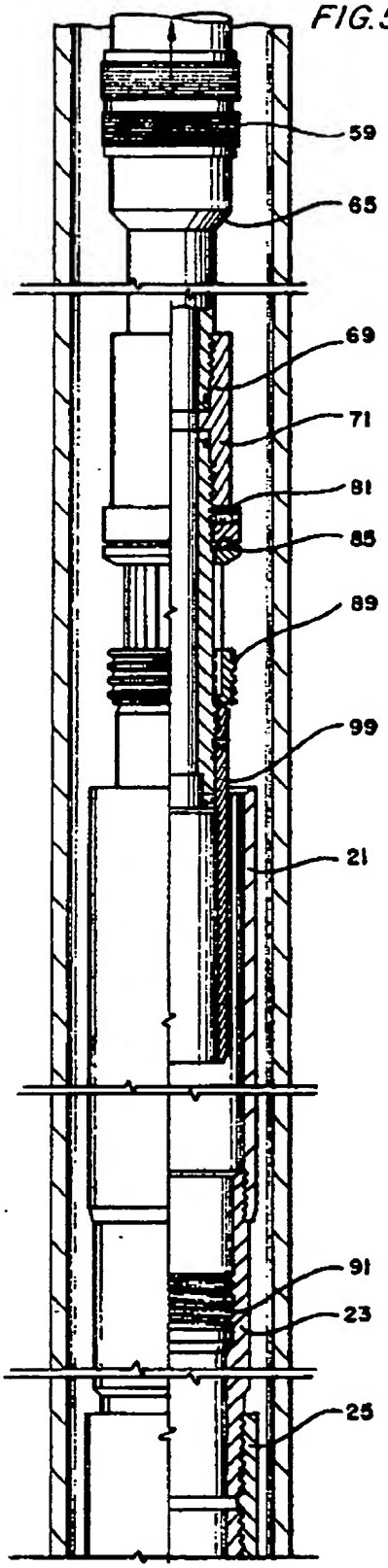
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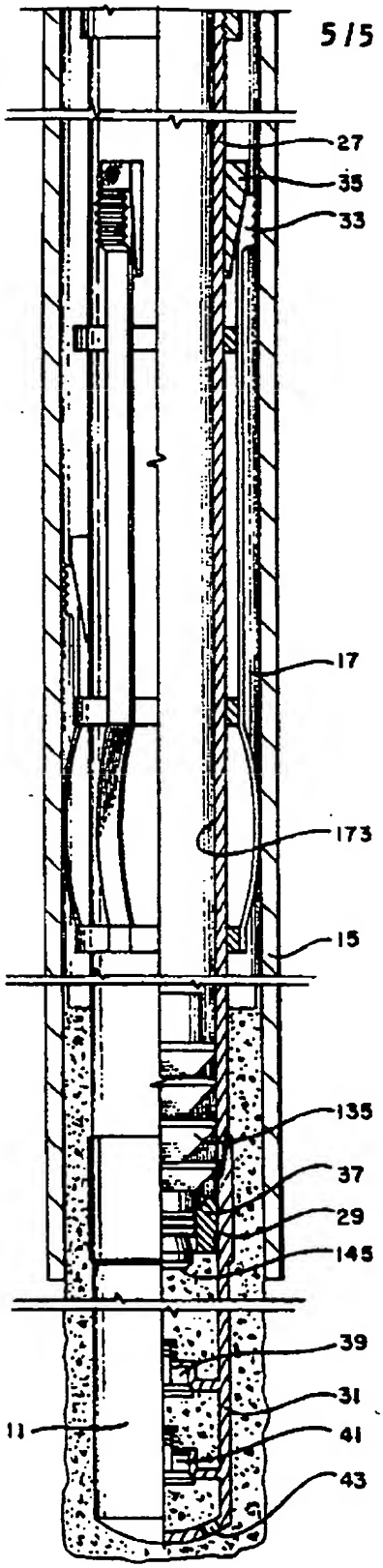
FIG.5B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SPECIFICATION

Apparatus and method for cementing a liner in a well bore

This invention relates generally to equipment for cementing liners in well bores and specifically to a well bore-liner cementing apparatus having a liner wiper plug for wiping the interior surfaces of the operating string and the liner after the cement flow therethrough.

A liner is a section of casing or tubing which is suspended in a well without normally extending to the surface. Cemented liners are used for many purposes including well control and reducing the initial cost of casing. Liners may be installed entirely within outer casing strings or partially within the casing and partially in an open hole.

Conventionally, a liner is set and cemented by first lowering the liner and a setting tool connected to an operating string into the well bore. The liner is hung, usually on slips, and the setting tool is usually but not always released from the liner. Cement is then pumped through the operating string into the liner and displaced from the liner, usually through a foot valve, into the annular space between the liner and the surrounding casing or well bore.

Usually a pump down plug is introduced into the liner string immediately behind the cement in order to separate the cement from the displacing fluid and to wipe the cement from the operating string and liner surface as the cement is pushed out of the liner into the surrounding annular space. Typically, the pump down plug which is to wipe the operating string and liner is pumped behind the cement until it engages a liner wiper plug and then the liner wiper plug and pump down plug are forced downwardly together in the liner string so as to displace cement therefrom and to wipe the liner walls.

U.S. Patent No. 3910349 to Joe R. Brown et al, entitled "APPARATUS AND METHOD FOR CEMENTING WELL LINERS", issued October 7, 1975, shows a liner cementing apparatus which includes a setting tool having a tubular mandrel connected in a pipe string for extension through the liner. A liner wiper plug is releasably disposed within the liner near one end of the mandrel. A seal assembly sealingly engages the exterior of the mandrel and the interior of the liner above the liner wiper plug. A latch assembly releasably connects the seal assembly to the liner so as to permit limited axial movement of the mandrel without disturbing the axial position of the seal assembly. After the liner is hung in position in the well bore, the setting tool is unlatched and moved axially a few feet to indicate to the operator at the surface that disengagement of the setting tool has occured. This tool exemplifies one type of problem associated with prior liner cementing tools which the present invention is directed to solve. In the prior design, the lower end of the setting tool mandrel initially extended within the liner wiper plug which is attached to the liner. When the lower end was withdrawn, it was sometimes difficult to reinsert the lower end into the liner wiper plug or to postively check whether reinsertion had been accomplished from the surface.

Another prior design which illustrates the type problem which the present invention is designed to overcome is illustrated in U.S. Patent No. 3835288 to Maurice P. Lebourg, entitled "LINER CEMENTING APPARATUS", issued January 18, 1972. The Lebourg device has a liner wiper plug attached by shear pins to the lower end of the operating string which is inserted within the liner. The problem encountered with this design is that axial movement of the operating string and setting tool to test disengagement causes the elastomeric elements surrounding the wiper plug to drag up and down along the interior surfaces of the liner. Thus could cause premature separation of the wiper plug from the setting tool. A pressure differential could also be created around the wiper plug during the axial movement which could cause premature separation.

The apparatus for cementing a liner in a well bore of the present invention includes a setting tool having an end adapted to be connected in a pipe string for extension through the liner, thereby creating an annular space between the setting tool and the liner. Seal means are carried by a select one of the setting tool and liner for forming a seal between the liner and the exterior of the setting tool in the annular space when the tool is extended within the liner. Connector means are carried by the setting tool for releasably connecting the liner to the setting tool. A wiper holder is connected to the setting tool end opposite the pipe string end. The wiper holder has an interior bore for receiving a wiper plug.

In the preferred embodiment, the setting tool has a tubular mandrel adapted to be connected in a pipe string for extension through the liner. Seal means carried by a select one of the setting tool and liner form a slidable seal between the liner and the exterior of the setting tool in the annular space when the tool is extended within the liner. Connector means carried by the setting tool releasable connect the liner to the setting tool. A cylindrically shaped wiper holder is connected to the setting tool end opposite the pipe string end and has an interior bore for receiving a wiper plug. The wiper plug has a tubular body having an upper extent adapted to be received within the setting tool opposite end and has a lower extent surrounded by elastomeric sealing elements. The wiper plug has a central

opening through which cement can be pumped into the liner through the pipe string and mandrel. The wiper plug is releasably disposed within the wiper holder, the elastomeric sealing elements being at least partly contained within the wiper holder prior to releasing the wiper plug. Pump down plug means are provided which are adapted for sliding and sealing engagement with the interior of the pipe string and mandrel, effecting a moveable seal behind the cement as it is pumped into the liner. The pump down plug means are engageable with the wiper plug and moveable therewith upon release of the wiper plug to effect a moveable seal behind the cement as the cement is displaced from the liner into the surrounding well bore.

In the method of cementing a liner in a well bore of the present invention, a setting tool having a tubular mandrel is connected to an operating string at one end and has an opposite end. A wiper holder is connected to the setting tool opposite end and an interior bore for receiving a wiper plug. The setting tool is lowered with the liner attached thereto into the well bore with seal means sealingly engaging the interior of the liner and the exterior of the mandrel. The liner is then anchored in place in the well bore. Then the setting tool can then be released from the liner and the tool is moved a selected distance to insure that the tool is detached from the liner. The wiper plug is contained within the wiper holder during this step. Cement is then pumped into the liner through the operating string and setting tool mandrel. A pump down plug means is then pumped which sealingly engages the operating string and mandrel behing the cement and engages the wiper cement is then pumped out of the liner into the surrounding well bore by forcing the pump down plug means and wiper plug through the liner. The setting tool is then removed from the well bore.

Additional objects, features, and advantages will be apparent in the description which follows.

Figure 1a is a side-elevational view in quarter section of the upper portion of the apparatus of the present invention in place in a well bore.

Figure 1b is a downward continuation of Fig. 1a showing the lower portion of the apparatus of the invention in place in a well bore.

Figure 2a is similar to Fig. 1a but shows cement being pumped through the apparatus, the cement being followed by a plug.

Figure 2b is similar to Fig. 1b but shows cement being pumped through the lower portion of the apparatus into the annulus between the apparatus and the surrounding well bore.

Figure 3 is a close-up, side cross-sectional view of the wiper holder of the apparatus of Fig. 1.

Figure 4 is a close-up, side cross-sectional view of the liner-wiper of the apparatus of Fig. 1 showing the liner-wiper engaging a landing show located in the lower portion of the apparatus.

Figure 5a is similar to Figs. 1a and 2a but shows the setting tool being removed from the apparatus after completion of cementing operations.

Figure 5b is similar to Figs. 1b and 2b but shows the bottom portion of the apparatus after completion of the cementing operations.

Referring now to Figs. 1a and 1b, there is shown a liner string 11 disposed near the bottom of a well bore 13. The well bore 13 can be lined by a casing string 15, which can extend to the surface of the well. An annular space 17 is formed between the liner string 11 and the surrounding well bore 13.

The liner string 11 includes a setting tool 19, a setting sleeve extension 21, a setting sleeve 23, a connecting member 25, and a liner hanger 27. The liner hanger 27 is connected to a liner 30, at the lower end of which is provided a landing area 29 and a cementing shoe 31.

The liner hanger 27 is provided with slips 33 and setting cones 35 by which the liner string is supported in the well bore. Such construction is well known in the industry and will not be described in detail here. The landing area 29 is provided with a landing collar 37 for receiving a liner wiper plug as will be more fully described later. The cementing shoe 31 is provided with back pressure check valves 39, 41 which permit the passage of cement from within the liner into the annular space 17 via ports 43.

The liner string 11 is initially attached by a rotatably releasable connector means 45 to the setting tool 19. The setting tool 19 is in turn connected to an operating pipe string (not shown) which extends to the surface of the well.

The setting tool 19, as shown in Fig. 1a, comprises a tubular mandrel 47 having a box connection 49 for connection to the pin end of an operating string. The internal diameter 51 of tubular mandrel 47 is substantially uniform throughout. The external diameter of tubular mandrel 47 decreases at the junction 56 of box connection 49 to form an intermediate portion 57 which is sized to be slidably received within the internal bore of setting sleeve extension 21. A set of suitable sealing rings such as Chevron-type rings 59 surround the lower extent of intermediate portion 57 and form a slidable seal between intermediate portion 57 and the interior sidewalls 61 of setting sleeve extension 21. The external diameter of intermediate portion 57 decreases further to form a lowermost extent 63 which joins intermediate portion 57 to form a downwardly facing shoulder 65.

The end 87 of tubular mandrel 47 opposite box connection 49 is externally threaded and adapted to engage the internal threads of the upper extent 69 of a cylindrical coupling 71. Cylindrical coupling 71 has an internally threaded lower end 73 which threadedly engages the externally threaded upper portion 75 of a tubular setting body 77. An upper bearing ring 79 is threaded onto the exterior of upper portion 75 and fixed in position by a set screw 81. A lower bearing ring 83 surrounds setting body 77 and together with ring 79 forms a race for ball bearings 85. Lower ring 83 is received upon a shoulder 87 formed at the junction of setting sleeve 23 and setting sleeve extention 21. The bearing arrangement permits the setting tool 19 and operating string to be rotated without axial displacement relative to the liner string 11. Lower bearing ring 83 is adapted to engage the shoulder 87 in the interior of linear string 11 to remain stationary during such rotation.

The linear string 11 is initially attached to the setting tool 19 by rotating connector means 45. The rotating connector means 45 as shown in Fig. 1a comprise a left-handed threaded nut 89 which engages coarse left-hand threads 91 on the interior of the setting sleeve 23. The interior of the nut 89 is provided with longitudinal slots for engagement with corresponding splines 93 on the setting tool 19. Thus, rotation of the setting tool 19 in the right-hand direction will cause the nut 89 to move upwardly on the splines 93 and to eventually disengage the threads 91 and the setting sleeve 23, effectively releasing the setting tool from the liner string.

The end 95 of setting body 77 opposite upper portion 75 is externally threaded and is adapted to threadely engage the upper internally threaded portion 97 of a cylindrical wiper holder 99.

In the setting tool configuration described above, the sealing rings 59 are carried above threaded nut 89 and forms seal in the bore of the setting sleeve extension 21. It should be understood that other arrangement are contemplated such as those in which the sealing elements are located below the theaded nut 89 on an extended portion of the setting body 95.

Wiper holder 99 is connected to the setting tool end opposite upper extent 69 and as shown in Fig. 1a has an interior bore 101 for receiving a wiper plug 103. A set screw 105 is provided to assure continued engagement between end 95 and upper internally threaded portion 97 of wiper holder 99.

The wiper holder 99 and wiper 103 are shown in greater detail in Fig. 3, which also shows a pump down plug 107 engaged within wiper 103 as will be more fully described later. As shown in Fig. 3, upper portion 97 of wiper holder 99 overlaps the external surface of end 95 of setting body 77. The internal diameter 117 of setting body 77 increases to form a shoulder 119 within end 95. An O-ring 109 is provided in the external surface of setting body end 95 to prevent the flow of fluids from the interior bore 101 between end 95 and portion 97. The internal diameter of upper portion 97 of wiper holder 99 increases slightly to form a shoulder 111 between upper portion 97 and the lower portion 113 of wiper holder 99. The internal diameter of lower portion 113 of wiper holder 99 is substantially uniform down to a lowermost extent 115 thereof.

Wiper plug 113 is releasably disposed within wiper holder 99 and has a central opening 121 through which cement can be pumped into the liner string 11 through the pipe string. Wiper plug 103 comprises a tubular body 137 including a lower extent 123 having an externally threaded upper end 127. End 127 threadedly engages the lower end 129 of a generally cylindrical upper extent 125 of wiper plug 103. A set screw 132 assures continued engagement between ends 127 and 129. Upper extent 125 is thus received on shoulder 119 within end 95 of setting body 77. Upper extent 125 is thus received within the setting tool end opposite the pipe string connection and releasably engaged, as by shear screws 131. One or more ports 133 communicate the central opening 121 with the interior bore 101 of wiper holder 99. The lower extent 123 of the wiper plug tubular body 137 is surrounded by elastomeric sealing elements 135 having upwardly extending concentric seals 139 for sliding and sealing engagement with the internal walls of the liner string 11. Sealing elements 135 are retained on the lower extent 123 of the tubular body 137 by bonding to a plurality of external flanges 141 in the exterior surface of lower extent 123.

Wiper plug 103 is shown in the preferred form with sealing elements 135 wholly contained within wiper holder 99. Other arrangements are understood as being within the scope of the invention including those in which one or more of the sealing elements 135 are positioned outside the wiper holder 99.

Lower extent 123 of tubular body 137 has an internally threaded end 143 adapted to threadedly engage a tubular landing member 145. The external diameter of landing member 145 gradually increases between the externally threaded end 147 and the lowermost extent 149 thereof forming a gradually sloping shoulder 152. Latch means such as slip-like members 153 ride on the external shoulder 152 of landing member 145. The latch means on the lowermost extent of wiper plug 103 are adapted to engage the landing collar 37 located below the wiper plug 103 in the interior of liner string 11.

The interior of lower extent 123 of tubular

body 137 is provided with a frictionally engageable surface 151 such as downwardly directed teeth 155.

As shown in Fig. 3, pump down plug means 159 can be provided which are adapted for sliding and sealing engagement with the interior of the pipe string and mandrel interior. The pump down plug means can comprise a plug body 163 having a nose portion 161 with a frictionally engageable surface 165 formed in the exterior surface between nose portion 161 and body 163. Frictionally engageable surface 165 of the plug means 159 is sized and adapted to engage the surface 155 to the wiper plug 103 when the pump down plug is pumped into the position shown in Fig. 3. An O-ring 167 can be provided in an annular groove 169 in the exterior surface of plug body 163 to provide sealing engagement between the pump down plug and wiper plug 103.

The operation of the apparatus of the present invention will now be described. Referring first to Figs. 1a and 1b, the device of the present invention is shown as it would appear running into the well bore and prior to the beginning of the cementing operations. Once the device is positioned at the desired depth, the cones 35 on liner hanger 27 are extended beneath slips 33 causing slips 33 to extend outwardly and engage the interior of the well bore or casing string 15 thus anchoring the liner into position. After hanging the liner in the conventional manner, circulation would be established by pumping circulating fluid down through the operating string, the setting tool 19, the liner string 11, and through the liner shoe 31 into the annular space 17 surrounding the liner string 11.

After circulation has been established, the setting tool 19 can be released from the liner string 11 by rotating the operating string in the right hand direction to release the splined nut 89 as shown in Fig. 2a. The operating string is then lifted a few feet to be sure that release has been effected. The distance that the setting tool 19 can be lifted is determined by the length of the portion 57 of tubular mandrel 47 which is received within setting sleeve extention 21 and by the position of seal rings 59 on the exterior of portion 57. Conveniently, a stroke of about five feet is permitted without loosing sealing engagement between seal rings 59 and the interior sidewalls 61 of setting sleeve extention 21.

A properly measured amount of cement is then pumped into the operating string, through the setting tool 19 and liner hanger 27 and out the ports 43 in cementing shoe 31 and into the annular space 17 between the liner string 11 and the well bore casing string 15. The pump down plug 159 is then placed in the operating string effecting a moveable seal behind the cement as it is pumped through the operating string, setting tool 19, and the central opening 121 of the liner wiper plug 103, and into the liner string 11. A displacing fluid is pumped behind the pump down plug 159 forcing the pump down plug 159 into the central opening 121 and into engagement with the liner wiper plug 103 as best seen in Fig. 3.

Further pressure, induced by pumping the displacing fluid behind pump down plug 159, will cause the frangible connection created by shear screws 131 between end 95 of wiper holder 99 and threaded portion 97 of wiper holder 99 to break, releasing both the pump down plug 159 and the liner wiper plug 103 for further movement down the liner string. The pump down plug 159 and the liner wiper plug 103 are moveable together, upon release of the liner wiper, to effect a moveable seal behind the cement as cement is displaced from the liner through the cementing shoe 31 into the annular space 17 surrounding the liner string 11. Upon reaching the landing area 29, the liner wiper plug 103 lands and seats in the landing collar 37 and the slip-like members 153 latch the liner wiper plug 103 and pump down plug 159 into the position shown in Fig. 4. At this point, cement should have been pumped upwardly into the annular space 17 surrounding the liner string to the desired level.

After cementing is complete, the setting tool 19 is removed from the well bore by lifting up on the operating string as shown in Fig. 5a.

An invention has been provided with significant advantages. The liner wiper plug portion of the apparatus of the invention is received within a wiper holder attached to the setting tool. Movement of the setting tool does not affect the wiper plug, removing the possibility of premature separation of the wiper plug as the setting tool is being lifted to test disengagement. The improved liner wiper plug configuration allows total control over the movement of the liner wiper plug and can thus guarantee positive latching when the pump down plug is pumped down. Because the liner wiper plug is contained within a wiper holder on the bottom of the setting tool, the pump-down plug can be tested in the tool before insertion in the well bore. The present configuration allows the setting tool to be lifted to test for disengagement without rubbing the wiper sealing elements against the interior of the setting sleeve. By locating the liner wiper plug within a wiper holder attached to the bottom of the tool, pressure differentials are eliminated which would otherwise exist between the setting tool lower end and the setting sleeve. The overall length of the setting tool is shortened where the liner wiper plug is located within the end of the tool.

While the invention has been shown in only one of its forms, it should be apparent to those skilled in the art that it is not thus

limited but susceptible to various changes and modifications without departing from the scope thereof.

CLAIMS

1. An apparatus for cementing a liner in a well bore, comprising: a setting tool having an end adapted to be connected in a pipe string for extension through said liner, thereby creating an annular space between said setting tool and said liner, and having an opposite end; seal means carried by a select one of said setting tool and liner for forming a seal between said liner and the exterior of said setting tool in said annular space when said tool is extended within said liner; connector means carried by said setting tool for releasably connecting said liner thereto; and a wiper holder connected to said setting tool opposite end, said wiper holder having an interior bore for receiving a wiper plug.

2. An apparatus for cementing a liner as in claim 1, further comprising a wiper plug releasably disposed within said wiper holder and having a central opening through which cement can be pumped into said liner through said pipe string.

3. An apparatus for cementing a liner as in claim 2, further comprising pump down plug means adapted for sliding and sealing engagement with the interior of said pipe string effecting a moveable seal behind said cement as it is pumped into said liner, said pump down plug means being engageable with said wiper plug and moveable therewith upon release of said wiper plug to effect a moveable seal behind said cement as said cement is displaced from said liner into said surrounding well bore.

4. The apparatus for cementing a liner as in claim 3, wherein said wiper holder is a cylindrically shaped member.

5. The apparatus for cementing a liner body having an upper extent adapted to be received within said setting tool opposite end, a lower extent surrounded by elastomeric sealing elements, and a lowermost extent.

6. The apparatus for cementing a liner as in claim 5, further comprising engaging means for releasably engaging said wiper plug within said wiper holder.

7. The apparatus for cementing a liner as in claim 6, wherein said engaging means are shear pins connecting said wiper plug upper extent and said setting tool opposite end.

8. The apparatus for cementing a liner as in claim 7, further comprising latch means on said wiper plug lowermost extent adapted to engage a landing collar located below said wiper plug in said liner interior.

9. An apparatus for cementing a liner in a well bore, comprising: a setting tool having a tubular mandrel adapted to be connected in a pipe string for extension through said liner, thereby creating an annular space between said setting tool and said liner, and having an opposite end; seal means carried by a select one of said setting tool and liner for forming a slidable seal between said liner and the exterior of said setting tool in said annular space when said tool is extended within said liner; connector means carried by said setting tool for releasably connecting said liner thereto; a cylindrically shaped wiper holder connected to the setting tool opposite end, said wiper holder having an interior bore for receiving a wiper plug; a wiper plug having a tubular body, said body having an upper extent adapted to be received within said setting tool opposite end and having a lower extent surrounded by elastomeric sealing elements, said wiper plug having a central opening through which cement can be pumped into said liner through said pipe string and mandrel, and said wiper plug being releasably disposed within said wiper holder, said elastomeric sealing elements being at least partially contained within said wiper holder prior to releasing said wiper plug; and pump down plug means adapted for sliding and sealing engagement with the interior of said pipe string and mandrel effecting a moveable seal behind said cement as it is pumped into said liner, said pump down plug means being engageable with said wiper plug and moveable therewith upon release of said wiper plug to effect a moveable seal behind said cement as said cement is displaced from said liner into said surrounding well bore.

10. A method of cementing a liner in a well bore with a setting tool, said setting tool having a tubular mandrel connected to an operating string at one end and having an opposite end, comprising the steps of: connecting a wiper holder to said setting tool opposite end, said wiper holder having an interior bore for receiving a wiper plug; lowering said setting tool with said liner attached thereto into said well bore, seal means sealingly engaging the interior of said liner and the exterior of said mandrel; anchoring said liner in said well bore; releasing said setting tool from said liner and moving said tool a selected distance to insure that said tool is disengaged from said liner, said wiper plug being at least partly contained within said wiper holder during said steps; pumping cement into said liner through said operating string and tool mandrel; pumping pump down plug means, sealingly engaging said operating string and mandrel, behind said cement into engagement with said wiper plug means; pumping cement out of said liner into said surrounding well bore by forcing said pump down plug means and wiper plug means through said liner; and removing said setting tool from said well bore.

11. An apparatus for cementing a liner in a well bore substantially as herein described with reference to and as illustrated in the

accompanying drawings.

12. A method of cementing a liner in a well bore substantially as herein described with reference to the accompanying drawings.

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